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NARROW VEIN BLASTHOLE STOPING:
Current Drilling and Blasting Technology

Yves C. Lizotte, M.Sc.A.,ing.

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ABSTRACT

This report reviews current drilling and blasting practices of longhole blasthole stoping for narrow vein mining. General references are provided and mining operations using this mining method are described, inasmuch as information could be obtained. The review aims at describing the drilling and blasting parameters and dimensions, and assessing the type of ground conditions under which the mining method has been applied.

1. INTRODUCTION

1.1 Overview

The objective of this report is to review the techniques and practices involved in longhole blasthole stoping for narrow-vein mining, with particular emphasis on the drilling and blasting aspects. This review has been sponsored by Echo Bay Mining Ltd. and the Northwest Territories through a Mineral Development Agreement.

Longhole blasthole stoping, or sublevel stoping, applied to narrow vein mining has been in use for (possibly) more than fifteen years in Canadian mines. It is now important to document practice to date since:

- Narrow-vein mining is now regarded as remaining a major source of precious metals supply during the next decade and technological improvements are necessary to keep narrow-vein mining competitive.

- A number of sub-economic deposits have been found which require new productive and low cost methods implementation before being brought into production.

- Powerful self-propelled drilling equipment is now available for working in narrow openings. The difficulty of hiring skilled miners for conventional narrow-vein mining methods (shrinkage, cut-and-fill) together with the intrinsic greater safety of blasthole stoping make it an attractive alternative to be closely considered.

Longhole narrow-vein blasthole stoping is herein (arbitrarily) defined as blasthole stoping applied to ore widths of less than two meters, with drilling of parallel holes from sublevels, with no more than three holes per row (width) and drillhole diameters not exceeding 80 mm.

1.2 Sources of information

This review of longhole narrow-vein blasthole stoping is based on the following sources of information:

- A computer search of the Mining Technology databank [MINTEC]. Sixty-one (61) references were produced with various combinations of keywords including 'blasthole, long-hole, vertical crater, thin, narrow, stringer, vein, stope, stoping, and drilling'. Twenty-nine (29) of these references were ordered and examined. About ten (10) technical papers were found to have some relevance to the current study.

- A computer search of the National Technical Information Services databank [NTIS]. The search was based on general keywords such as 'blasthole or long-hole' and 'mining or stoping' with too few references to qualify with 'narrow-vein, thin, etc..' Twenty-four (24) references were produced. Four (4) references were ordered and examined.

- A computer search of the Engineering Index databank [EI]. Keywords were the same as those used in the NTIS search but qualified with 'narrow- vein', etc.. Sixteen (16) references were produced. Two (2) references were ordered and examined.

- Examination of a general reference databank compiled by the author comprised of over three hundred (300) general references regarding fragmentation, mining methods and blasting.

- A visit by the author to Echo Bay Mining's Lupin Mine in July 1989, with discussion with staff and examination of internal reports.

- Information gathered by communicating with five mining companies, a drill manufacturer, and staff of the CANMET Mining Research Laboratories.

2. GENERAL DESCRIPTION OF STOPING METHOD

2.1 Conditions of Application

Stope development for blasthole stoping in narrow veins is quite similar to sublevel stoping in wider deposits. As previously stated the maximum stope width is restricted to 2 m, implying only one drift per level and approximately parallel drilling of blastholes.

This stoping method applies to vertical or sub-vertical deposits, vein dips at least 50 degrees. It is essential that the ore vein be fairly continuous with a well defined 'planar regularity' between sublevels. Larsen et al (1989) have recently reviewed the main technical parameters necessary for the effective application of the method. [This technical paper, prepared by Boart Canada Inc. employees, is the most explicit recent publication reviewing sublevel stoping for narrow vein mining and has been used as a first source of information in preparing the present review]. Larsen et al (1989) also state that the recommended stope width be 0,5 m or greater.

Excluding requirements for 'planar continuity' of the ore vein, parameters which impact the greatest on required development, drilling and blasting procedures and, consequently the applicability of the method are the competencies of the ore, the footwall and hangingwall. Because, by definition, it is an open stoping method, any amount of wall sloughing strongly marks dilution considering the ore widths involved. Additional care in drilling and blasting practices and added expenses/development for natural or artificial ground support in some instances may prohibit profitable application of the method.

2.2 Development

Development must be minimized, within the restrictions of the orebody geometry, equipment capabilities and rock competencies. Drilling accuracy limitations and planar regularity of the vein govern sublevel intervals selection. Drilling up and down holes from intermediate sublevels allows for greater spacings, although downhole drilling is apparently more accurate and productive; Larsen et al (1989) illustrate a typical development with down holes only, while operators generally drill shorter up holes (e.g. Dome Mines, Opémiska).

The current trend is to dimension sublevels to accommodate relatively narrow drill carriers. Bar & arm setups are however still used, particularly in very narrow veins. Drill carriers require a minimum width of 2 m but sublevels may be slightly larger depending upon available development mucking equipment. Recommended height is at least 3 m (Larsen et al (1989)) allowing for efficient 1.2 m rod changes.

Ore blocks are typically developed with four sublevels and a drawpoint- mucking level. The standard practice is to retreat from a slot raise at one end of the block, instead of starting from a central slot and retreating in both directions [which offers greater flexibility in sequencing but requires more development for access]. The length of the blocks/stopes are restricted by mucking and operating efficiency or the need to leave intermediate pillars for local/regional support. The narrow width allows the drawpoint level to be totally silled out in the ore. Drawpoint spacing will depend on the type of mucking equipment used (i.e. mucking machines, LHDs, remote), ease of access and the size of the stope blocks. Development for access can involve raises and ramps. Also, drift development may be necessary for access to a suitable location for cable bolt installations.

2.3 Drilling and Blasting

There is apparently no mining operation which has attempted to optimize drillhole diameter for narrow-vein sublevel stoping. The usual practice has been to employ

available drills, perhaps used for other methods or in wider parts of the deposits. In this case the drilling and blasting patterns are accordingly adjusted to provide an adequate powder factor for fragmentation and, through control of drilling accuracy and detonation sequencing, protect stope walls and minimize artificial supports.

The restricted geometry of the stope limits the choice of possible drilling patterns. Sublevel narrow-vein stoping is generally restricted to three holes per row, whatever the hole diameters used. Drilling patterns are variants of basic 3:3, 3:2, 3:1 and 2:1 patterns. When the basic pattern is selected a suitable burden is determined by trial and error, with the most common burden being 1.2 m (Larsen et al (1989)). The simple stope geometry also restricts the choice of possible initiation sequences. [Few operations surveyed have fully reported sequencing and likely it may often be left to the blaster's judgement]. Perceived and measured hole accuracy (including setup location, starting angle and deviation-wandering) will influence pattern, burden and spacing selection.

To date the common practice has been to use ANFO type products and occasionally water gels for wet holes. Products with higher relative weight strengths such as emulsions for general use have not been found to be used, likely because of wall damage which may result. Lighter strength explosives with lower detonation velocities, such as ANFO-polystyrene mixes, could potentially be applied to reduce wall damage, given that adequate fragmentation can be maintained.

3. RANGE OF OPERATING PARAMETERS

Characteristic ranges of operating parameters are supplied herein rather than all inclusive possible values since it was not possible to survey all mines applying sublevel stoping to narrow-vein mining.

Stope block heights have been determined to vary between 30 and 80 m. Block height is apparently strongly related to sublevel interval, whereby the block is planned for a maximum of four drilling sublevels. Block lengths are limited by operational efficiency, ore grades and the need for natural pillars; maximum length is about 105 m. Minimum stope width is about 0.5 m, Bond Gold Mine excavating a 0.8 m (32 in) wide stope to mine a vein which varies between 0.25 and 0.38 m (Larsen et al (1989)).

Drillhole diameters characteristically range from 41 mm (1 5/8 in.) to 64 mm (2 1/2 in.). An older operation, mining veins 1.5 m wide with a sublevel stoping variation used 89 mm (3 1/2 in.) drifter drills mounted on a stope jumbo (Swerdfeger (1972)).

Sublevel interval which depends on deposit characteristics (geometry and continuity), ground stability and hole accuracy varies between 6 m and 20 m. Larsen et al (1989) recommend a maximum sublevel interval of 12.2 m (40 ft); this value probably assumes

only down hole drilling on sublevels. When up hole drilling is done, holes are normally shorter than down holes, likely influenced by hole accuracy and operational efficiency. Assessing these parameters through drill tests will indicate the balance to be found between effects associated with these factors and the relative cost of sublevel development. Maximum down hole lengths vary between 7.3 m and 16.8 m, and up holes are limited to about 12.2 m. Certain mines 'dump' up holes 65 to 75 degrees towards the open face, to produce a smooth back and/or provide down holes an additional free face for blasting. Down holes are generally aligned to the orebody dip, parallel to the cross-section. The trend is to use drill carriers/stope jumbos which will fit in the sublevels; electric-hydraulic drills are also more popular.

Mucking equipment used in the drawpoints is not different from conventional equipment for drawpoint loading. The bottom of the stope is usually silled out for the length of the block. Drawpoint spacing varies from 9 m to 13 m.

The basic drilling patterns are categorized as variants of 3:3, 3:2, 3:1 and 2:1 patterns. A typical nominal burden is 1.2 m, values up to 1.5 m seen for 3:3 patterns and down to 0.46 m for 2:1 in very narrow stopes (distance between row with two holes to row with one hole). Patterns are in general symmetrical, with respect to the stope centreline and the stope length. Variants have been adapted with off-centre middle holes (Dome Mines) or un-symmetrical patterns (Opémiska) as a function of local conditions or to meet particular objectives. Note that no sublevel stoping operation for narrow-veins appears to have attempted staggered 1:1 patterns such as used in narrow vein reef-type mining (Brinkman et al (1987), Wilson and Miller (1973), Anon (1973), Anon (1982), Sen (1985)).

Detonation sequencing is apparently no source of concern (or complexity), the simple geometry limiting alternatives. However, the information gathered and examined to date is incomplete to fully document present practices. Short period delays are likely used (approx. 25 ms) in multi- hole blasts. The following sequences are in current use or have been attempted:

- Simultaneous firing of all holes in a row (for 3:3, 3:2, 3:1 and 2:1 patterns).

- Firing of a central hole, footwall hole, hangingwall hole (3:3 pattern).

- Firing of a central hole, hangingwall hole, footwall hole (2:1 pattern).

Given that hole deviation and delay scatter can be controlled, short delays between all holes will reduce ground vibrations. Firing the hole closest to the hangingwall last in the sequence may contribute in protecting the wall from damaging vibrations. Testing

and determination of an appropriate firing sequence is just as important to the successful implementation of the stoping method as initial determination of drilling patterns, burdens and spacings.

4. TECHNICAL PARAMETERS OF MINES APPLYING METHOD

The sources of information stated in Section 1.2 were used to document technical parameters related to sublevel stoping for narrow veins in various mines. The technical data gathered is fully listed, in standard form, in Appendix A to this report. The reader is invited to examine these forms for all technical specifications and to know the type of information requested in the short survey conducted.

The description of the stoping operations will be limited to main design and operational parameters. Salient features will be highlighted where appropriate.

4.1 Lupin Mine

Echo Bay Mining Ltd. have sponsored this review as part of a study to improve operating practices for their sublevel stoping applied to narrow vein mining at the Lupin Mine. Consequently, current drilling and blasting procedures are now under review and will not be described here. Technical specifications are however contained in Appendix A in the same format as other operations, to facilitate comparisons.

4.2 Dome Mines

Testing and operation of sublevel stoping for narrow-vein mining at the Dome Mines, Placer Dome Ltd., Timmins, Ontario, is the best documented case found to date. Testing was the topic of a full paper by Robertson (1981) with additional information provided by Robertson (1986), Larsen et al (1989) and communication with J. Vehkala of Dome Mines.

Stoping widths are 1.5 to 2.1 m. Sublevels are variably spaced (likely to follow ore) with values ranging from 12.2 m to 15.2 m. The operation favors downhole drilling and hole deviation is reported to be less than 1% (Vehkala). The rock in the initial test area is described as highly competent (Robertson (1981)). Other tests were unsuccessful (Robertson (1986)) because of excess dilution and large blocks of waste toppled into the open stope, even when cable bolting was done from drilling sublevels; conversion to inverted bench mining was examined. J. Vehkala reports current dilution to be 10 %, without specifying calculation method.

The standard drilling pattern is 3 holes per row with a nominal burden of 1,2 m. The most interesting features are the measures taken to protect the hangingwall. Firstly, the centre hole is not exactly in the middle of the stope; for a 1.9 m drilling width at 0.8 m

from footwall and 1.1 m from hangingwall, (Robertson (1986)), for a 1.5 m width, 0.6 m from footwall, 0.9 m from hangingwall, (Vehkala). Secondly the standard blasting practice is to sequence centre holes first, footwall holes second and hangingwall holes last. This ensures that an open face is initiated before detonation on the hangingwall side, contributing to reduction of vibration/pressure against the wall.

Sublevel stoping for narrow vein mining is apparently a viable alternative at Dome Mines. Particular conditions may require they develop alternatives in the future for either inappropriate conditions or lack of skilled miners.

Robertson (1986) correctly summarizes results of their tests and conditions of application:

"Sublevel blasthole stoping has proved to be a viable method for narrow veins in a competent host rock. However, extensive application of the mining method is limited by the following conditions:

- Longhole stoping lengths must be capable of standing open without extensive ground support.

- The method is not as selective as shrinkage stoping when mining discontinuous veins.

- Excessive dilution can occur in stopes with weak wall rocks and/or high in *situ* stress."

These conditions quite simply make or break the technical feasibility and profitability of sublevel stoping for narrow-vein mining. It is unfortunate that none of the mining operations have documented rock strengths (including RQD) in quantitative manners. Equally important to note the emphasis on *in situ* stress - the method being likely harder to manage as mining deepens.

4.3 Opémiska Mine

By discussion with CANMET staff it was determined that Minnova Inc. apply sublevel stoping to narrow-vein mining at Division Opémiska Mine, Chapais, Québec. A short questionnaire was sent out to the mine, the results of which are contained in Appendix A.

The ore width is 1.5 m and the standard sublevel interval is 16.2 m. Conventional pneumatic drills are used (Bar & arm or drill carrier ?) with 50 mm holes. The rock is described as mainly competent with weak jointing, 75% of stopes, the rest is more jointed. Fragmentation is excellent using ANFO. Up holes are shorter and dumped forward 70 degrees; hole lengths indicate only down holes are used wherever possible.

Artificial ground support includes cable bolts and 'Swellex'. Dilution is estimated to be 30%.

The mine reports that two drilling patterns are used. In soft rock a 3:1 pattern with a nominal burden of 1.5 m (row with one hole is centered at 0.75 m). In hard rock the pattern shown is a 2:1 with a burden of 1.37 m (4.5 ft); in this case the single hole is closer to the front row (0.46 m) than to the back row (0.91 m). This pattern, likely determined by experimentation, indicates that the single hole, shot alone, must have a smaller burden than the two holes on a row probably shot simultaneously. This shows that this mining operation has been able to adjust drilling/blasting patterns to suit local conditions. They have continuously applied the method for at least the last three years.

4.4 Bell Creek Mine

Larsen et al (1989) report that sublevel stoping for narrow-vein mining is used at Canamax Resources' Bell Creek Mine. Information was obtained from this publication, a survey by N. Billette and S. Dufresne of CANMET in June 1989 and a short questionnaire sent to the mine.

This mining operation does not appear to be satisfied with results to date and will continue mining in the future by shrinkage. Larsen et al (1989) indicate a wide sublevel spacing of 15 m with very competent rock; the survey by CANMET staff indicates a 11 m sublevel spacing, extensive ground support requirements and dilution estimated at 30%. A 3:3 pattern is also used; the same firing sequence as Dome Mines is used (middle hole, footwall hole second, hanging wall last). In addition, holes on the hangingwall side were loaded with Trimtex, Primeflex or with a lighter load to reduce wall damage.

4.5 Bond Gold Mine

Application of sublevel stoping at St-Joe Minerals' Bond Gold mine is also reported by Larsen et al (1989). Efforts were made to contact technical staff of St-Joe Minerals. The company is now restructured in Canada under the name of Bond Gold Canada Inc. and the mine referred to previously is the Golden Patricia Mine, 70 km south-west of Pickle Lake, Ontario. The survey questionnaire was completed by staff at the mine.

In this case the ore vein is very narrow, ranging from 0.3 m to 0.45 m. Nominal stope width is 0.8 m. Sublevel spacing is relatively small, varying from 6 m to 10 m, with maximum hole lengths of 7.3 m (41 mm diameter). Larsen et al (1989) indicate patterns of 2:1, while the blasting pattern indicated on the survey shows that 3:2 patterns have equally been tested. Holes were dumped forward towards the open stope at 68 to

75 degrees. Productivity is relatively low at 20 tonnes per man-shift (procedure for computing this productivity was not specified).

The reported dilution of 50 percent and the comments concerning sloughing of walls during blasting indicate the right combination of drilling and blasting parameters could not be determined for this mine. The survey indicates longhole stoping has been totally abandoned in favor of shrinkage stoping at the Golden Patricia Mine.

4.6 Doyon Mine

From the Annual General Meeting of CIM in 1989 it was seen that the Doyon Mine near Noranda, Québec uses sublevel stoping. Technical personnel were contacted at Cambior Inc. and at the Doyon mine.

The application of blasthole stoping to narrow veins at this mining operation can be typified as simply an extension of the standard blasthole stoping. The mine reports ore widths of 2 to 5 meters and the size of openings, drillhole diameters, mucking equipment justify the previous statement. It is thus hard to evaluate separately the success of the method in narrow parts of the deposit. In addition, no direct estimate of dilution can be made; the mining operation has the *fortunate* problem of usually achieving higher tonnages of ore than estimated (cutting of high grade samples).

Three particular reported items are worthy of notice. First, the mine has very little hole deviation on 12 to 15 m holes, which can be attributed to favorable geology and possible the use of slightly larger drill holes (76 mm) compared to similar operations (e.g. Lupin, Opémiska). Secondly, the blasting sequence is specifically designed by the engineering staff (3:2 patterns, all holes in a row fired simultaneously). Finally it must be noted that this mining operation tested diluted ANFO (Lomex) as the prime explosive; no specific motives were given for abandoning this practice.

4.7 Other Mines

It is probable that other mines using sublevel stoping have attempted mining narrow veins in this manner; unfortunately no additional publications were found to this effect. Certain mining operations are considering trying sublevel stoping in the near future (e.g. Seabright's Forest Hill Mine - CIM 1989 Meeting).

5. DISCUSSION

Sublevel stoping for narrow vein mining has recently become an attractive alternative due to changing work conditions in the mining industry. Among these changes are the relatively higher labour costs, the greater reliance on narrow vein deposits, the relative lack of skills of the new labour force and the desire for safer conditions with increased

mechanization of standard operations. Given the desire to use the method and the appropriateness of the method for the deposit configuration, the design must focus on two factors which govern consequent profitability; ground control and dilution.

This review has only determined qualitatively the rock competency required to apply the stoping method. Robertson (1986) states that a prerequisite is that the wall can hold freely (or partly artificially supported) over the stope height. This can only be determined by somewhat extensive laboratory and *in situ* testing. Systematic cable bolting is feasible, at a cost. Ground conditions are also important since they impinge on dilution.

The computation procedures, the vein configuration and its planar continuity affect resultant dilution. These factors are not directly controllable. Ground conditions, stoping widths, hole deviation, delay scatter and general drilling and blasting procedures affect dilution and must be closely studied. The review has also indicated that a specific dilution may be acceptable to one operator and not to another (i.e. 30% dilution at Opémiska and at Bell Creek). This depends on the possible reduced dilution achievable with another stoping method and the relative costs of each method.

Traditional blast design usually implies selecting a pattern to achieve a specific overall powder factor while minimizing drilling. This consequently implies use of a relatively high strength explosive to guarantee adequate fragmentation. Recognizing the dramatic impact of ground control and dilution on the method, a novel approach to parameter determination is suggested. In this case a broader range of drillhole diameters and explosive strengths should be studied. Larger diameter drillholes may reduce deviation. Decoupled ANFO, by dilution with polystyrene (Nielson and Heltzen (1987)) or salt (Day and Webster (1982)) lowers velocity of detonation, reducing vibrations and subsequent wall damage. A large set of initial combinations could be analyzed for resultant fragmentation (assessed to be more than adequate in this review and providing sufficient leeway for modified designs) using simple empirical formulas (Cunningham (1987)). A short list can then be examined with respect to local explosive strengths or 'cell powder factors' (King et al (1988)) to estimate vibrations induced in the walls.

6. CONCLUSIONS

Once established that the orebody is appropriate, dilution and ground control dictate the profitability of longhole blasthole stoping for narrow- vein mining. Implementation of the method requires thorough testing of parameters, including the various possibilities discussed above. Future studies of the method would necessitate complete ground condition assessments and complete economic analysis.

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APPENDIX A: COMPILED DATA FROM MINING OPERATIONS

The information gathered from the literature review and communications with mine operators is presented here in the raw form it was collected. Measurement units are given in the original forms supplied. When several sources were used parameters are not always consistent; no attempt was made to change these values. The standard form of the survey questionnaire is as follows.

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE:

WIDTH OF ORE

STOPE DIMENSIONS

SUBLEVEL INTERVAL

DRAWPOINT LAYOUT

DRIFT DIMENSIONS

DENSITY OF ORE

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL

OREBODY DIP

TYPE OF DRILL, STEELS, BITS

HOLE DEVIATION

DRILLING PATTERN

BLASTING PATTERN

LENGTH OF HOLES (UP, DOWN OR BOTH)

RELATIVE DIP OF HOLES

EXPLOSIVES

INITIATION/SEQUENCING

DRILLHOLE DIAMETER

ESTIMATED DILUTION

APPROXIMATE MUCK SIZE

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING)

STUDIES PERFORMED/COMPARISONS MADE

GENERAL COMMENTS

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE: ECHO BAY MINING - LUPIN MINE, NORTH WEST TERRITORIES [West Zone]

WIDTH OF ORE 1.5 m

STOPE DIMENSIONS Variable. Maximum stope height usually 80 m blocks.

SUBLEVEL INTERVAL 20 m

DRAWPOINT LAYOUT Made for 5 cu.yd. LHDs, drawpoint spacing 13 m.

DRIFT DIMENSIONS 2 m wide by 3 m high (sufficient for 2 cu. yd. LHDs)

DENSITY OF ORE 3.53

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL Quartzite and phyllite walls approx. 22 000 psi, ore approx. 38 000 psi. Relatively strong rock and walls. Holds well over height of blocks. A fault runs parallel to part of the West Zone, approximately 1 m in hanging wall which causes some sloughing/dilution problems, requires careful planning and blasting.

OREBODY DIP 75 to 90 degrees

TYPE OF DRILL, STEELS, BITS Tamrock 322, Round steels, button bits.

HOLE DEVIATION 3 % (or more ?)

DRILLING PATTERN 2:1. One hole on each side of ore, one hole centered and approximately 0.8 m in front of two side holes. (**)

BLASTING PATTERN 2:1. Front hole initiated, followed by two side holes initiated simultaneously. Nominal burden: 0.75 m (**)

LENGTH OF HOLES (UP, DOWN OR BOTH) Maximum 10 m.

RELATIVE DIP OF HOLES Up holes are dumped 75 degrees towards open stope to provide a smooth back and also for cleaner break of down holes (free face).

EXPLOSIVES ANFO, Powermex (boost) and cap.

INITIATION/SEQUENCING Electric. 25 ms delays, front hole shot, the two side holes are shot simultaneously.

DRILLHOLE DIAMETER 2 in. (50 mm).

ESTIMATED DILUTION (Previously with large equipment, dilution was estimated to be 43%). Now dilution is possibly 30 to 35%.

APPROXIMATE MUCK SIZE With previous 3:2 pattern visually assessed to be 95% less than 150 mm, with the largest pieces not bigger than 400 mm.

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING)

Computed as approximately 64 t/m.s., direct mining labour, 12 hour work shifts, assuming 1.0 m of dilution according to earlier estimates.

STUDIES PERFORMED/COMPARISONS MADE Internal studies were made assessing Raise Platform Mining and comparing sublevel stoping to shrinkage.

GENERAL COMMENTS Sources of information: Reports and site visit, July 1989.

** Modifications now under study.

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE: PLACER DOME - DOME MINES, TIMMINS, ONTARIO.

WIDTH OF ORE 5 ft. (1.5 m) [5 to 7 ft]

STOPE DIMENSIONS 65 degree dip of ore - Cross section of stope 9ft x 10ft (?) [55 degree average] [1986 - Test block 83 m long x 70 m height, 17 m sublevel spacing]

SUBLEVEL INTERVAL 40 ft - 50 ft Variable

DRAWPOINT LAYOUT 40 ft interval 2.7 m x 3.7 m Wagner 1.5 cu.m. Scooptrams

DRIFT DIMENSIONS 8 ft x 10 ft.

DENSITY OF ORE 2.81

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL

Ankerite veins in spherulitic pillow lava. Wall rocks: schistose greenstone. Test area (1981): Highly competent.

OREBODY DIP 60 to 70 degrees

TYPE OF DRILL, STEELS, BITS Bar & Arm with Gardner-Denver DH 123, BCI Drill Carrier with Secan S36 drill. Originally with Bar & Arm, 1.25 in. hexagonal rods.

HOLE DEVIATION Less than 1%.

DRILLING PATTERN Burden 48in, 3 holes per row, from centre 2ft to F.W., 3ft to H.W. [Line burden 4 ft nominal]

BLASTING PATTERN Short period delays, Centre hole #1, F.W. #2, H.W. #3.

LENGTH OF HOLES (UP, DOWN OR BOTH) Down only, depends on distance between suvlevels. Up & down 30ft maximum.

RELATIVE DIP OF HOLES Dip of ore. [1981 - Up holes on top sublevel inclined at 65 degrees to the blasting face to minimze bootlegging].

EXPLOSIVES ANFO or Watergel [1986 - Amex II, Powermex 300 cartridged water gels for wet holes].

INITIATION/SEQUENCING Electric - Nonel

DRILLHOLE DIAMETER 2 in.

ESTIMATED DILUTION Approximately 10%.

APPROXIMATE MUCK SIZE Less than 16 in.

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING) 1989 - 300 ft/m.s. [180 ft/m.s.] [17.2 t/m.s. compared to 16 for conventional shrinkage]

STUDIES PERFORMED/COMPARISONS MADE - Method in use since 1977. Comparisons with conventional shrinkage.

GENERAL COMMENTS

Sources of information: B.E. Robertson, 1981 and 1986 papers. Paper by Boart Canada, 1989. Communication with J. Vehkala, Dome Mines.

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE: MINNOVA INC. - DIVISION OPEMISKA, CHAPAIS, QUEBEC.

WIDTH OF ORE 5 ft.

STOPE DIMENSIONS 350 ft x 5 ft x 160 ft x 70 degrees

SUBLEVEL INTERVAL 53 ft.

DRAWPOINT LAYOUT 30 ft center line 8.5 ft x 9.5 ft on footwall

DRIFT DIMENSIONS 8.5 ft x 9.5 ft

DENSITY OF ORE 11 cu. ft./ short ton.

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL Competent rock with weak jointing for 75% of the stopes. Rest is more jointed = 25%.

OREBODY DIP 70 degrees

TYPE OF DRILL, STEELS, BITS Atlas Copco BBC 120

HOLE DEVIATION Less than 5%

DRILLING PATTERN Down: 45 ft to 55 ft Up: 30 ft to 40 ft. In soft rock a 3:1 pattern is used. Typically holes on side of ore and one in the middle, then 2.5 ft and one hole in the middle. In hard rock a 2:1 pattern, holes apparently not on waste/ore contact. 1.5 ft burden, one hole in the middle, then a 3 ft burden with two holes again.

BLASTING PATTERN

LENGTH OF HOLES (UP, DOWN OR BOTH) Down: 45 ft to 55 ft, Up: 30 ft to 40 ft.

RELATIVE DIP OF HOLES "70 degree uppers + vein dib to ore dib for downs" (?) - holes aligned with ore.

EXPLOSIVES ANFO

INITIATION/SEQUENCING Nonel + 1 cartridge Forcite 75%.

DRILLHOLE DIAMETER 2 in.

ESTIMATED DILUTION 30%

APPROXIMATE MUCK SIZE 90% less than 6 in.

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING) Drilling 129 t/m.s. Blasting 192 t/m.s. Mucking 110 t/m.s.

STUDIES PERFORMED/COMPARISONS MADE

GENERAL COMMENTS 16 ft cable bolt 1 per row, 12 ft Swellex 1.5 per row, 12 ft Super Swellex 1 per row (to be started).

Source of information: J.-M. Couture, M.Huot, Minnova Inc., Division Opémiska, Chapais, Qc.

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE: CANAMAX RESOURCES, BELL CREEK MINE

WIDTH OF ORE 6 TO 20 ft

STOPE DIMENSIONS [Width 6 to 20 ft]

SUBLEVEL INTERVAL 15 m

DRAWPOINT LAYOUT [320 Cavo loaders - mucking from drawpoints into cars, also use slushers]

DRIFT DIMENSIONS 2.4 m x 2.7 m [open raising 2.1 m x 1.5 m]

DENSITY OF ORE 2.8 tonne/cu. m

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL [Rock bolts 1.2 m x1.2 m pattern, 1.5 m length. Swellex 1.5 m x 1.5m 2.4 - 3.0 m length. Screen and straps to try to control H/W in stopes].

OREBODY DIP 65 - 70 degrees

TYPE OF DRILL, STEELS, BITS BCI-2 Carrier with Secan S36 drill

HOLE DEVIATION Up to 2 ft on 45 ft holes.

DRILLING PATTERN 3:3, middle hole centered.

BLASTING PATTERN 4 ft line burden (1.2 m)

LENGTH OF HOLES (UP, DOWN OR BOTH) 45 ft (The ore seam structure is very consistent. The host rock is also very competent allowing for particularly long distances between sublevels) [11 m from CANMET survey]

RELATIVE DIP OF HOLES

EXPLOSIVES Nilite and Tovex 1kg/tonne, Trimtex or Primaflex on hanging- wall side, or lighter ANFO load.

INITIATION/SEQUENCING Nonel and B-line Middle hole, footwall hole, hang-ingwall hole last.

DRILLHOLE DIAMETER 2 in.

ESTIMATED DILUTION Approximately 30% dilution was experienced in the sub-level retreat stopes. However these stopes will be exhausted this year and all stoping will be by shrinkage methods.

APPROXIMATE MUCK SIZE Maximum 2 ft blocks, except where hole deviation is large.

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING) 280 ft/m.s.

STUDIES PERFORMED/COMPARISONS MADE

Dilution from labor consideration or equipment - lack of definition drilling, type of mineralisation: "These three areas are of particular concern at the Marchill property where the vein is very irregular and dips from 70 degrees to 40-45 degrees. Compounding this problem is the lack of continuity in grade of the vein in particular stopes. The determination of stope ends is also difficult without extensive diamond drill information"

GENERAL COMMENTS

Sources of information: Paper by Boart Canada, 1989. Survey by N.Billette and S. Dufresne, CANMET 1989. Communication with M. Hogan, Canamax Resources.

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE: ST-JOE MINERALS - BOND GOLD MINE, PICKLE LAKE, ONTARIO. Now Bond Gold Canada Inc. - Golden Patricia Mine, 70 km SW of Pickle Lake.

WIDTH OF ORE 12 to 18 inches.

STOPE DIMENSIONS 32 in. wide nominal [1989 - From figure block height approx. 30 m.]

SUBLEVEL INTERVAL 6 to 10 m.

DRAWPOINT LAYOUT 8m center to center spacing

DRIFT DIMENSIONS 2.7m x 2.7m

DENSITY OF ORE 2.7 tonnes/m^3

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL

OREBODY DIP 80 degrees average.

TYPE OF DRILL, STEELS, BITS BCI Carrier equipped with DH 99. 7/8 Noranda rope thread, 1 5/8 Bit Boart.

HOLE DEVIATION

DRILLING PATTERN 2:1, 32 in. spacing, 18 in. burden (center hole from side holes)

BLASTING PATTERN 3-2-3-2-3-2

LENGTH OF HOLES (UP, DOWN OR BOTH) 10ft to 35ft depending on sub-levels.

RELATIVE DIP OF HOLES 68° to 75°

EXPLOSIVES AMEX

INITIATION/SEQUENCING NONEL c/w FORCITE PRIMER

DRILLHOLE DIAMETER 1 5/8 in.

ESTIMATED DILUTION 50%

APPROXIMATE MUCK SIZE Minus 18 in.

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING) 235 ft/m.s. 20 tonnes/m.-s.

STUDIES PERFORMED/COMPARISONS MADE Nil

GENERAL COMMENTS "Mining method determined unsuitable due to sloughing on stope during final stages of blasting."

Sources of information: Boart Canada 1989 Paper. Attempts were made to contact St-Joe Minerals technical personnel. Contacted Doug Hayes, Chief Engineer, Golden Patricia Mine.

SPECIFICATIONS: BLASTHOLE STOPING FOR NARROW-VEIN MINING

MINE: DOYON, 40 km EAST OF ROUYN-NORANDA, QUEBEC.

WIDTH OF ORE 2-5 m, quite continuous.

STOPE DIMENSIONS Variable length, typically about 75 m, Height = 45 m

SUBLEVEL INTERVAL 15 m

DRAWPOINT LAYOUT From a footwall, 3m x 3m less than 45°

DRIFT DIMENSIONS 3 to 4 m wide by 4 m high, accomodates JS 3.5yd^3 LHDs

DENSITY OF ORE 2.85

QUALITATIVE/QUANTITATIVE ROCK APPRAISAL Good quality, jointing sometimes a problem. Hangingwall stands well.

OREBODY DIP 70°

TYPE OF DRILL, STEELS, BITS Pneumatic Atlas Copco BBC 120. Hexagonal steels and button bits.

HOLE DEVIATION Not a problem. Almost none on 12-15 m holes.

DRILLING PATTERN 3:2 with a 1.5 m burden in 2 m wide stopes.

BLASTING PATTERN All holes in a row are fired simultaneously.

LENGTH OF HOLES (UP, DOWN OR BOTH) Up and down holes used, up to 15 m.

RELATIVE DIP OF HOLES Parallel, follow cross-sections (no dumping forward).

EXPLOSIVES ANFO with primers at bottom and collar. Lomex was tested and abandoned.

INITIATION/SEQUENCING 25 ms delays. Firing sequence is decided by engineering staff.

DRILLHOLE DIAMETER 2 1/2 in

ESTIMATED DILUTION Difficult to estimate. Generally more tonnes are drawn than the computed reserves. Grade of mine output is frequently better than estimates due to elimination of high grade samples in computations.

APPROXIMATE MUCK SIZE Generally fine muck, very good, less than 1.5m x 1.5m Average is 6 to 8 in, largest pieces about 2 ft.

TOTAL PRODUCTIVITY (MINING WITH/WITHOUT MUCKING) 175 ft/m-s (Shrinkage 38 t/m-s)

STUDIES PERFORMED/COMPARISONS MADE

GENERAL COMMENTS

Information obtained partly from R. Leclerc, Chief Engineer, Cambior Inc., and mainly from M. Lachance, Chief Engineer, Lac Minerals, Doyon Mine.